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GEOLOGY, ENERGY AND MINERAL RESOURCES ASSESSMENT OF THE SALT LAKE AREA, NEW MEXICO

BY

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**GEOLOGY, ENERGY AND MINERAL RESOURCES
ASSESSMENT OF THE SALT LAKE AREA,
NEW MEXICO
by**

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SUMMARY

This assessment of the Geological, Energy, and Mineral (GEM) Resources in the Salt Lake area (GRA) was performed during the summer of 1982. The report area is located in northwestern Catron County, New Mexico, and contains two Wilderness Study Areas (WSA) - Mesita Blanca and Eagle Peak - containing a total of 62,960 acres (254.67 km sq.).

The report area is located in west-central New Mexico. It is near the southern edge of the Colorado Plateau physiographic province and is at the north edge of the Datil-Mogollon volcanic field of New Mexico and Arizona. About two-thirds of the report area is covered by Tertiary and Quaternary volcanic flows and associated rocks. The remaining third (northwest part) is an area of Mesozoic sedimentary rocks.

The known mineral deposits in the Salt Lake GRA are salt, sand and gravel, and construction stone. In addition, there are important known resources of coal that have not been developed. There are known prospects and occurrences of sand and gravel, construction stone, coal, and uranium. There may be additional resources of petroleum and tin within the report area although no deposits or prospects have been identified. Favorability and the level of confidence maps are included for: a) salt, b) coal, c) oil and gas, and d) sand, gravel, and construction stone.

The highest favorability classification within the WSAs is for coal in the outcrop areas of the known coal-bearing units of the Mesaverde Group. The classification is 4-C (for explanation of classification scheme, see text).

The assessment of GEM resources in the report area is at a low level of confidence, mainly because of few published references on the area, but also due to widespread Tertiary/Quaternary cover present in the area. The time available for this investigation did not permit a field examination.

Recommendations of new data needed include a field examination in outcrop areas, specifically in the Datil Formation, in both WSAs. The objective would be to assess the possibility of occurrence of the volcanic units of this general region known to be favorable for tin or uranium deposits. More detailed assessments of the coal resources and of the oil and gas potential are also recommended. During the same field examination, the area around the Zuni Salt Lake should be examined to look for any further salt resources that may occur in the north part of Eagle Peak WSA.

INTRODUCTION

This report is one of a series prepared for the U.S. Bureau of Land Management (BLM) as part of the BLM program for assessment of known and potential resources in previously designated Wilderness Study Areas (WSAs) in New Mexico. As required by the BLM program, preliminary assessments have been made of the potential for Geological, Energy, and Mineral Resources (GEM Resources) in the subject area. The methodology applied for this project was as follows:

1. a search of available unpublished and published information on the designated WSAs and the surrounding areas,
2. grouping of the WSAs into suitable areas for study (termed GEM Resource Areas, or GRAs), taking into account the local and regional geological settings and the constraints of the BLM-specified reporting format,
3. identification of environments favorable for the occurrence of GEM resources in each GRA,
4. reinterpretation as indicated by the results of the field work, and
5. land classification for GEM resource potential in the areas studied, including assessments of favorability and of the level of confidence in each Wilderness Study Area.

The assessments are necessarily preliminary, and the BLM has recognized this project by designating its program as Phase One of their planned assessment of GEM resources in Wilderness Study Areas. The total effort expended by Geoexplorers on this GRA was about one man-month.

In this report, resources are defined as mineral or fossil fuel deposits amenable to economic development under current or reasonably anticipated

conditions. The terminology follows that of the U.S. Bureau of Mines and the U.S. Geological Survey (1976; 1980). Included in resources are:

1. known reserves (measured, indicated and inferred),
2. deposits currently known to exist but not currently recoverable because of either technological or economic constraints, and
3. deposits not currently known but for which favorable geological environments can be demonstrated.

The term resources includes: reserves, conditional resources, hypothetical resources, and speculative resources.

The Salt Lake GRA is located in the northwestern Catron County, along the western edge of New Mexico (fig. 1). Access to the area is from U.S. Highway 60, between the town of Quemado and the Arizona state line. The GRA is in the St. Johns 1:250,000 scale quadrangle map. The town of Quemado is located two miles east of the GRA as shown on the 1:250,000 scale map (fig. 2). Unimproved roads lead northwesterly from U.S. 60 to the two WSAs. Both WSAs are in the Socorro BLM District and have been designated in the BLM Wilderness Inventory as:

Mesita Blanca	NM-020-018	19,440 acres	78.63 km sq.
Eagle Peak	NM-020-019	43,560 acres	176.20 km sq.
Total		63,000 acres	256.67 km sq.

The two WSAs, and other features of the GRA, are shown on figure 2.

PHYSIOGRAPHY

The Salt Lake GRA is located near the southern edge of the Colorado Plateau physiographic province. Most of the GRA, plus an extensive area to the south and east, is covered by Tertiary and Quaternary volcanic flows and associated pyroclastic rocks. The northwest third of the GRA does not have volcanic cover and the terrain there is more typical of the Colorado Plateau.

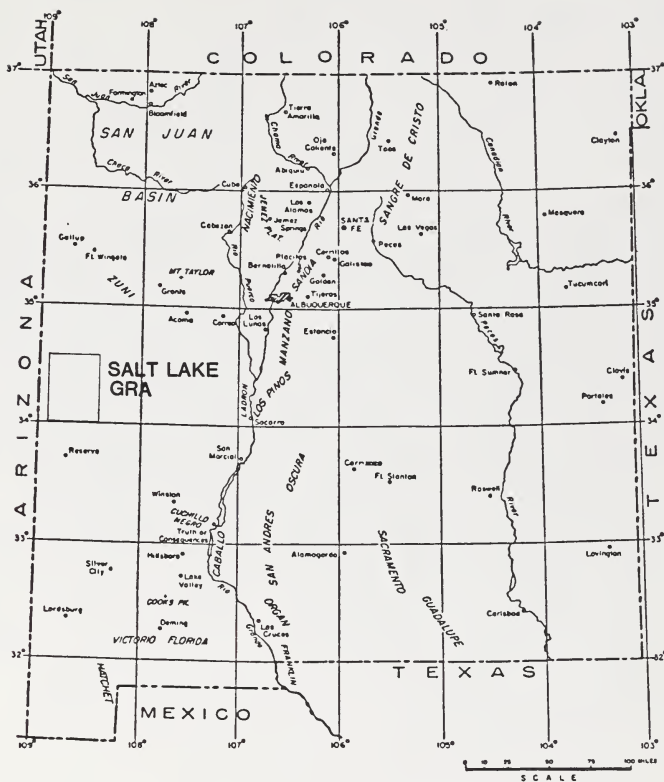


FIG. 1 LOCATION MAP OF NEW MEXICO, SHOWING OUTLINE OF THE SALT LAKE GEM RESOURCES AREA. After Northrup, 1961.

The altitude in the GRA ranges from about 6200 feet to 8950 feet above sea level. The lowest altitudes are in the northwest part of the area and the highest are in the Gallo Mountains in the southeast part of the area.

The drainage system is not well developed in this area, except in the extreme southeast part, because of the arid climate and low topographic relief. Most of the Salt Lake GRA drains northwesterly toward Sargo Creek, Carrizo Wash, and the Zuni Salt Lake. The Zuni Salt Lake occupies an undrained depression which may have formed as a result of a volcanic collapse structure. There has also been speculation that the depression resulted from solution of salt known to be present in the Permian strata west of this area (Willard, et al., 1959). There are many small topographic basins of internal drainage in the area as shown on figure 2, but the major drainage is into Largo Creek or Carrizo Wash and ultimately into the Colorado River. Around the Zuni Salt Lake (within a four mile radius) there are many similar but smaller undrained depressions that contain playas similar to the Zuni Salt Lake, though less well developed. Some of these are in the north part of the Eagle Peak WSA. Other similar depressions are found south of U.S. Highway 60 in T1S-R19W and T2S-R20W.

GEOLOGY

Regionally, the Salt Lake GRA is located on the north edge of the Datil-Mogollon volcanic field which is underlain by Cretaceous, Triassic and Permian strata. Outcrops of most of these strata and the Precambrian crystalline basement rocks are exposed to the surface in the Zuni Mountains, which are located about 50 miles to the northeast. The area, south of the Zuni-Defiance uplift and north of the Mogollon Rim is sometimes called the Mogollon Slope.

Figure 3. **LEGEND**
FOR

GEOLOGIC, ENERGY AND MINERAL RESOURCES MAPS

Scale of all maps is 1:250,000 or as otherwise indicated.

LITHOSTRATIGRAPHY

After Quahada Engineering, 1979

QUATERNARY	Qs	SEDIMENTARY DEPOSITS - Mainly alluvial gravel, sand and silt in flood plains, terraces, fans and pediment cappings. Locally includes dune sand, lake deposits and landslide masses. Shown only in areas where they are of appreciable thickness or extent.
	Qb Qv	VOLCANIC ROCKS - Qb, basaltic flows, tuffs and cinders distinguished from older basalts. Locally includes trachyte, latite, andesite and also some intrusive rocks. May include some flows of Pliocene age. Qv, undifferentiated volcanic rocks.
	QTs	SEDIMENTARY DEPOSITS - includes Gila Conglomerate and other stream and lake deposits mainly in intermontane areas. Consists of loosely to firmly consolidated gravel, sand, silt, local clay, gypsum, marl, limestone, diatomite and some intercalated basalt flows and felsic tuff beds.
TERTIARY	Ts	SEDIMENTARY ROCKS - includes conglomerate, sandstone, siltstone, limestone, and tuffaceous beds. May include interbedded volcanic units ranging from rhyolite to andesite.
	Tbs	SEDIMENTARY ROCKS - Sedimentary part of the Bidahochi Formation (Pliocene) in northeastern Arizona consisting of sandstone, siltstone and locally bentonitic clay.
	Tds Tda	DATIL FORMATION - Tda, andesite and basaltic andesite flows and intrusive rocks. Tds, clastic rocks of volcanic fragments.
	Tbc	BACA FORMATION - fluvial clastic sequence of probably Eocene age.
CRETACEOUS	Kmv	MESAVERDE GROUP undivided - includes Gallup Sandstone (lower) and Crevasse Canyon Formation (upper). Contains significant coal reserves.
	Km	MANCOS SHALE - gray marine shale, in part interbedded with overlying Mesaverde Group and Dakota Sandstone.
	Kd	DAKOTA SANDSTONE - gray-brown quartzose sandstone, locally may contain coal.
TRIASSIC	Tc	CHINLE FORMATION - mainly redbeds of continental origin, with minor gray shale and sandstone.

SPECIAL SYMBOLS OF STRUCTURAL FEATURES

After U.S. Geological Survey

	Contact — Dashed where approximately located; short dashed where inferred; dotted where concealed
	Contact — Showing dip; well exposed at triangle
	Fault — Dashed where approximately located; short dashed where inferred; dotted where concealed
	Fault, showing dip — Ball and bar on downthrown side
	Normal fault — Hachured on downthrown side
	Fault — Showing relative horizontal movement
	Thrust fault — Sawteeth on upper plate
	Anticline — Showing direction of plunge; dashed where approximately located; dotted where concealed
	Asymmetric anticline — Short arrow indicates steeper limb
	Overturned anticline — Showing direction of dip of limbs
	Syncline — Showing direction of plunge; dashed where approximately located; dotted where concealed
	Asymmetric syncline — Short arrow indicates steeper limb
	Overturned syncline — Showing direction of dip of limbs
	Monocline — Showing direction of plunge of axis
	Minor anticline — Showing plunge of axis
	Minor syncline — Showing plunge of axis

Strike and dip of beds — Ball indicates top of beds known from sedimentary structures

	Inclined		Horizontal
	Vertical		Overturned

Strike and dip of foliation

	Inclined		Vertical		Horizontal
--	----------	--	----------	--	------------

Strike and dip of cleavage

	Inclined		Vertical		Horizontal
--	----------	--	----------	--	------------

Bearing and plunge of lineation

	Inclined		Vertical		Horizontal
--	----------	--	----------	--	------------

Strike and dip of joints

	Inclined		Vertical		Horizontal
--	----------	--	----------	--	------------

Note: planar symbols (strike and dip of beds, foliation or schistosity, and cleavage) may be combined with linear symbols to record data observed at same locality by superimposed symbols at point of observation. Coexisting planar symbols are shown intersecting at point of observation.

SPECIAL SYMBOLS

FOR ENERGY AND MINERAL RESOURCES

KNOWN DEPOSITS AND OCCURRENCES

 -O Oil field	 -C Coal deposit	 -Mineral orebody - as specified with symbol
 -G Gas field	 -C Coal occurrence	 -Mineral deposit - as specified with symbol
 -Os Oil shale		 -Mineral occurrence - as specified with symbol
		 -Mineral district (Fig.=inserted map)

EXPLORATION AND/OR MINING ACTIVITY

MINERALS AND COAL

 Mineral deposit, mine or prospect with recorded prod.	 Vertical shaft	 Active gravel or clay (cl) pit
 Prospect or mine with no recorded production	 Inclined shaft	 Inactive gravel or clay (cl) pit
 Accessible adit, or tunnel	 Active open pit, or quarry	 Exploration hole with data available
 Inaccessible adit, or tunnel	 Inactive open pit, or quarry	 Exploration hole without data
		 Mining district (Fig.=inserted map)

PETROLEUM

 Oil well	 Show of gas	 CO ₂ - or He-helium- rich well
 Oil and gas well	 Show of oil	 Dry well - abandoned
 Gas well	 Show of oil and gas	
	 Shut-in well	

GROUND WATER

 Water well of special importance	 Brine	 Thermal water
 Water well of high yield	 Mineral water	 Radioactive water
 Flowing water well		 Thermal point

ENERGY RESOURCES

O Oil	C Coal	U Uranium
G Gas	Cb Lignite (brown coal)	Th Thorium
Os Oil shale	Cp Peat	Gt Geothermal
Ot Tar sands		

MINERAL RESOURCES

METALS

Al Aluminum	Cu Copper	Mo Molybdenum	Tl Thallium
Sb Antimony	Ga Gallium	Ni Nickel	Sn Tin
As Arsenic	Ge Germanium	Nb Niobium or Columbium	Ti Titanium
Be Beryllium	Au Gold	Pt Platinum group	W Tungsten
Bi Bismuth	Fe Iron	RE Rare earth	V Vanadium
Cd Cadmium	Pb Lead	Rh Rhenium	Zn Zinc
Cr Chromium	Li Lithium	Sc Scandium	Zr Zirconium and Hf Hafnium
Cs Cesium	Mn Manganese	Ag Silver	
Co Cobalt	Hg Mercury	Te Tellurium	

NONMETALS - INDUSTRIAL MINERALS

ab Abrasives	dl Diatomite	fs Feldspar	mg Magnesian refractories
al Alum	Nonmarine and marine evaporites and brines	F Fluorite (fluorspar)	ml Mica
as Asbestos	pt Potash	gs Gem stones	ph Phosphate
ba Barite	na Salt - mainly halite	ge Graphite	pl Pigment and fillers
be Bentonite	gy Gypsum and anhydrite	he Helium	qz Quartz crystals
ca Calcite	nc Sodium carbonate or sulfate	ki Kaolin	sl Silica sand
cl Clay	bn Boron minerals	ky Kyanite and related minerals	s Sulfur
Construction materials:	ni Nitrates	ls Limestone	tc Talc
cs Crushed stone	Sr Strontium	im Lithium minerals	ze Zeolites
la Lightweight aggregates, includ.:	Br Bromine		hm Humate
pm Pumice and volcanic cinders	cc Calcium chloride		
pe Perlite	mg Magnesium compounds		
ec Expanded clay, shale, slate			
vm Vermiculite			
sg Sand and gravel			
cr Cement raw materials			
bs Building stones			
li Lime			

SPECIAL GEOLOGICAL FEATURES

POINT OF SPECIAL GEOLOGIC INTEREST

m Mineral occurrence	s Structural, bedding, foliation, etc.,	u Radioactive spring
f Fossil locality	b Brecciation, shear zone, etc.,	g Thermal spring
v Volcanic phenomenon	y High yield spring	a Extensive rock alteration
t Stratigraphic sequence	p Spring with mineral water	r Lithologic type locality

FAVORABILITY POTENTIAL AND LEVEL OF CONFIDENCE FOR MINERAL RESOURCES

FAVORABILITY:

1A - Undefined

1 - Not favorable - combine with either B, C, or D

2 - Low

3 - Moderate

4 - High

} combine with either A, B, C, or D

LEVEL OF CONFIDENCE:

A - Insufficient data

B - Indirect evidence

C - Direct evidence

D - Abundant direct and indirect evidence

Lithostratigraphy - Rock Units

The rock units in the southern half of the Salt Lake GRA are Tertiary and Quaternary volcanics of the Datil-Mogollon volcanic field. In the northern half of the GRA, the volcanics are mostly absent and a Mesozoic sedimentary sequence is exposed at the ground surface. The oldest rocks that crop out within the Salt Lake GRA are the Triassic Chinle Formation; the oldest within the two WSAs are the Cretaceous Mancos Shale. In the subsurface, rocks of Permian and Pennsylvanian age are important because of the possibility of petroleum accumulation in these rocks.

Pennsylvanian

Magdalena Group

In northwest Catron County, the Magdalena Group is composed of a basal Sandia Formation (sandstone) overlain by the Madera Limestone. The Sandia Formation is up to 400 feet thick and the Madera is up to 1700 feet thick (Hilpert, 1969). Both of these formations contain reservoir rocks and the Madera carbonates contain potential source rocks for petroleum. The Pennsylvanian is absent in the northern third of the Salt Lake GRA (because of the Zuni-Defiance uplift) and thickens to the south. The maximum thickness of Pennsylvanian rocks in the Salt Lake GRA is about 1000 feet, and in the two WSAs the maximum is about 500 feet.

Permian

Abo Formation

The Abo Formation consists of a sequence of red and gray mudstones and lenticular sandstones, mostly of Wolfcampian age, with possibly some Leonardian age rocks in the upper part. The Abo Formation is as much as 900 feet thick in Catron County.

Yeso Formation

The Yeso Formation consists of a sand formation of fluvial origin with minor interbedded siltstone and limestone. The thickness of the entire Yeso Formation in northwest Catron County is roughly 1000 feet in the subsurface. The Yeso Formation does not crop out in the Salt Lake GRA, but in other nearby outcrops is composed mainly of massive or crossbedded orange-red sandstone.

Glorieta Sandstone

The Glorieta Sandstone, of Leonardian age, is a gray to white, medium- to coarse-grained quartzose sandstone. The thickness of the Glorieta Sandstone in Catron County is about 200 feet.

San Andres Limestone

The San Andres Limestone is also Leonardian and is the youngest formation of Paleozoic age in western New Mexico. The San Andres consists of a gray cherty limestone with interbedded shale, sandstone, and locally some gypsum or anhydrite. The thickness of the San Andres Limestone in northwest Catron County is about 400 feet (Hilpert, 1969).

Triassic

Chinle Formation

The Triassic rocks in northwest Catron County comprise roughly 1000 feet of a mainly red bed section with minor gray shale and sandstone. The entire Triassic section is assigned to the Chinle Formation in this report, although locally some of the beds in the lower part of the Triassic section in this area could be assigned to the Moenkopi Formation. The Chinle Formation is an important host for uranium deposits in New Mexico and Arizona.

Cretaceous

Dakota Sandstone

Rocks of Jurassic and earliest Cretaceous age are absent in Catron County. The Triassic rocks are overlain unconformably by the Dakota Sandstone, which is about 100 feet thick. The Dakota consists of mainly a gray-brown quartzose sandstone of fluvial and marginal marine origin; locally it may contain some coal beds.

Mancos Shale

Conformably overlying the Dakota Sandstone is the Mancos Shale, which is composed of a gray marine shale with minor sand lenses. In northwest Catron County the Mancos section is about 400 feet thick.

Mesaverde Group

The Mesaverde Group is Upper Cretaceous in age, and contains important coal beds in many areas of New Mexico. In northwest New Mexico, the Mesaverde Group is divided into (in ascending order) the Gallup Sandstone, Crevasse Canyon Formation, Point Lookout Sandstone, Menefee Formation, and Cliff House Sandstone. In northwest Catron County the Mesaverde Group is 1200 feet thick, and in this report the Mesaverde Group is not divided. The coal beds in the Salt Lake GRA are in the middle and upper parts of the Mesaverde Group, in the equivalent of the Crevasse Canyon Formation. The outcrop of the Mesaverde Group crosses the area from northeast to southwest and is important as the host for known coal resources. Most of the area of both WSAs is either in the outcrop area of the Mesaverde Group or has Mesaverde rocks at a shallow depth.

Tertiary

Baca Formation

Unconformably overlying the Cretaceous rocks is the Baca Formation, which is a fluvial sequence of probable Eocene age. In northern Catron County the Baca Formation is about 700 feet thick and is made up of red and gray mudstone, arkosic sandstone, and conglomerate (Willard, 1959). The Baca Formation is favorable for uranium deposits (Milligan and Birdseye, 1968; Maassen, 1980).

Datil Formation

The term "Datil Formation" is used for a complex sequence of volcanic and volcanoclastic rocks up to 2000 feet thick in west-central New Mexico. In the area of the Salt Lake GRA the Datil Formation consists of volcanic flows and plugs of andesite and basalt, tuffaceous units and associated sedimentary rocks.

Bidahochi Formation

The Pliocene Bidahochi Formation crops out in the north-central part of the Salt Lake GRA and unconformably overlies the Cretaceous Mancos Shale. The formation is 150 feet or less in thickness in this area (May et al., 1980). The Bidahochi Formation has been informally divided into three members, as follows: a lower lacustrine member comprised of a basal conglomerate with overlying mudstone, claystone and limestone, a middle volcanic member of basaltic and basaltic detritus and an upper fluvial member of mid-Pliocene age. Apparently only the upper member, comprised of conglomerate, sandy limestone, micritic limestone and arkose, crops out in the Salt Lake GRA.

Later Tertiary and Quaternary sediments also crop out in the GRA. These

consist mainly of stream and lake deposits but may include alluvial fan deposits. Conglomerate, sandstone, siltstone, limestone, marl, clay and tuffaceous sediment, gypsum and diatomite occur with varying degrees of consolidation. Rhyolitic to andesitic volcanic rock is interbedded with the older of these sediments; basalt and felsic tuff is intercalated with the younger sediments (Maassen, 1980).

Quaternary

Basalt

Volcanic flows of basaltic to andesitic composition unconformably overlie the Datil Formation. For the purposes of this report their principal importance is that they mask the older structure and lithology in parts of both of the WSAs. Locally, these units may also contain resources of basaltic scoria or aggregate. Some of the flows may be of Late Tertiary age but these are not differentiated in this report.

Sediments

The Quaternary sediments are mainly alluvial sand, gravel and silt. Locally some dune sands and landslide deposits are included.

Structural Geology and Tectonics

The geological structure in the north half of the Salt Lake GRA is better known than that of the south half. In the north part of the GRA southeasterly dipping Mesozoic sedimentary rocks are exposed. The ages of the rock sequence are Triassic (Chinle Formation) and Cretaceous (Dakota Sandstone, Mancos Shale, and Mesaverde Group).

The depth to the Precambrian in the Salt Lake GRA ranges roughly from 4000 feet in the southwest corner of the area to 6000 feet in the east-central part.

In the south half of the GRA the Mesozoic sedimentary rocks are covered by Tertiary and Quaternary volcanic units and associated sediments. Most of the Mesita Blanca WSA is in the area of Cretaceous outcrop and most of the Eagle Peak WSA is in the area of Tertiary and Quaternary cover.

Paleontologic Documentation

The surface rocks of the south part of the Salt Lake GRA are mostly not fossiliferous. The Tertiary volcanics that cover much of the area do not contain any fossils but the interbedded pyroclastic units can be expected to contain some preserved fossilized plants and animals. The Mesozoic sedimentary units exposed in the north part of the GRA, including the Mesaverde Group, Mancos Shale, Dakota Sandstone, and Chinle Formation carry some fossils. The Mesaverde Group and the Chinle Formation are mostly continental sediments and are known to contain non-marine fossilized plants and animals. The Mancos Shale is well known for Upper Cretaceous marine fossils in many parts of the western United States. The Dakota Sandstone is both fluvial and marginal marine. The Dakota interval has some plant fragments and locally some coal beds. The Mesozoic section in the Salt Lake GRA has not been extensively studied, mainly because of the geographic remoteness of the area.

Geologic History and Paleogeographic Development

There are no Precambrian outcrops in the Salt Lake GRA or vicinity, so the Precambrian in this area is known only from drill-hole information and from outcrops in the region. The nearest Precambrian outcrops are granitic intrusive rocks in the Zuni Mountains, 50 miles northeast. About an equal distance to the south, in Grant County, Precambrian metamorphic rocks are

exposed. West-central New Mexico was part of a stable interior craton throughout Late Precambrian time. The area was also subject to erosion throughout the early and middle Paleozoic into the Pennsylvanian Period. During mid-Pennsylvanian time (Des Moinesian or Missourian) a shallow sea encroached from the south. To the north, the Zuni-Defiance Platform was a positive element during the Pennsylvanian Period. During the Permian Period a source area from the south became more important and deposited sediments of the Abo and Yeso Formations, Glorieta Sandstone and San Andres Limestone. This southerly source area became larger during the Triassic and Jurassic Period. During the Triassic, the clastic sediments of the Chinle Formation were deposited. Jurassic sediments were also deposited, but were removed by erosion during the Early Cretaceous. Marine conditions returned during the Cretaceous, when the marginal marine Dakota Sandstone and the marine Mancos Shale were deposited. Continental deposition then returned to the area. The clastic sediments of the Mesaverde Group are preserved, including the coal beds in the middle part of the Mesaverde.

During the late Cretaceous and early Tertiary time, the Laramide orogeny elevated the Zuni uplift in the area to the northeast of the Salt Lake GRA and produced essentially the structure that has persisted to the present. The Zuni uplift may have started to rise during the late Jurassic (Hilpert, 1969, p. 29).

During the early Tertiary the fluvial clastic sediments of the Baca Formation were deposited and then partially eroded. The mid-Tertiary (Oligocene) volcanics of the Datil Formation covered the beveled surfaces of the older Tertiary and Mesozoic rocks. The oldest of the volcanic flows of the Datil Formation were basaltic to andesitic in composition. The later flows of the Datil Formation are rhyolitic, but these have not been recognized in the mapped area (fig. 2). After the deposition of the Datil

volcanics and associated sediments, there was a period of erosion until the Late Tertiary when sediments of the Bidahochi Formation were deposited. Another series of volcanic flows were extruded in the late Tertiary or Quaternary. These younger flows are basaltic to andesitic. During most of the Quaternary the area has been subject to erosion. There has been deposition of alluvial sediments in the topographically low areas and the sediments have been modified by development of sand dunes and landslide deposits.

ENERGY AND MINERAL RESOURCES

In the Salt Lake GRA there are known deposits of salt, sand and gravel, and construction stone. There are also important coal resources but the coal is undeveloped. Specific deposits of coal have not been identified but the general area of coal occurrence is fairly well known.

Known Mineral Deposits with Recorded Production

Salt

1. Zuni Salt Lake
Location: Sec. 31, T3N-R18W
Status: Producer (Oct. 1979)
Reference: MILS 0350030276
2. Unnamed
Location: Sec. 29, T3N-R18W
Status: Unknown
Reference: Zuni Salt Lake 7 1/2 degree quad

Sand and Gravel

3. Materials Pit 65-32-S
Location: Sec. 14, T1S-R20W
Status: Past producer
Reference: MILS 0350030120
4. Materials Pit 65-33-S
Location: Sec. 13, T1S-R20W
Status: Past producer
Reference: MILS 0350030121

5. Materials Pit 68-23-S
Location: Sec. 7, T1S-R16W
Status: Past producer
Reference: MILS 0350030128
6. Materials Pit 69-21-F
Location: Sec. 13, T3S-R17W
Status: Past producer
Reference: MILS 0350030131
7. Materials Pit 70-7-F
Location: Sec. 18, T1S-R16W
Status: Past producer
Reference: MILS 0350030132

Construction Stone

8. Materials Pit 66-22-S
Location: Sec. 25, T1S-R21W
Status: Past producer
Reference: MILS 0350030125
9. Material Pit 68-12-S
Location: Sec. 6, T1S-R18W
Status: Past producer
Reference: MILS 0350030127
10. Materials Pit 68-25-S
Location: Sec. 14, T2S-R17W
Status: Past producer
Reference: MILS 0350030130
11. Materials Pit 68-9-S
Location: Sec. 25, T3S-R18W
Status: Past producer
Reference: MILS 0350030126

Known Prospects and Occurrences with no Production Recorded

Sand and Gravel

In addition to the five known past producers of sand and gravel listed in this report, the file of the Mineral Industry Location System (MILS file) of the U.S. Bureau of Mines lists six locations within the Salt Lake GRA as deposits of sand and gravel without known production. Two additional deposits, not listed in MILS, are shown as gravel pits on the U.S. Geological Survey topographic map of the Tejana Mesa SW 7 1/2 minute quadrangle. The eight locations are as follows:

- | | |
|---------------|----------------------------------|
| 12. Location: | Sec. 6, T1S-R18W |
| Status: | Unknown |
| Reference: | MILS 0350030200 |
| 13. Location: | Sec. 32, T4N-R16W |
| Status: | Unknown |
| Reference: | MILS 0350030201 |
| 14. Location: | Sec. 24, T1N-R20W |
| Status: | Unknown |
| Reference: | MILS 0350030204 |
| 15. Location: | Sec. 25, T1S-R21W |
| Status: | Unknown |
| Reference: | MILS 0350030203 |
| 16. Location: | Sec. 10, T1S-R19W |
| Status: | Unknown |
| Reference: | MILS 0350030208 |
| 17. Location: | Sec. 7, T1S-R16W |
| Status: | Unknown |
| Reference: | MILS 0350030274 |
| 18. Location: | Sec. 20, T1N-R17W |
| Status: | Unknown |
| Reference: | Tejana Mesa SW 7 1/2 minute quad |
| 19. Location: | Sec. 21, T1N-R17W |
| Status: | Unknown |
| Reference: | Tejana Mesa sw 7 1/2 minute quad |

Construction Stone

No specific prospects of construction stone have been identified but additional resources undoubtedly exist in the vicinity of the known past producers, and in other areas.

Coal

The Salt Lake GRA contains significant resources of coal in the Crevasse Canyon Formation of the Mesaverde Group. The approximate areas of outcrop of the coal-bearing beds are shown in figure 2. Most of the area of both WSAs, Mesita Blanca and Eagle Peak, is underlain by coal. In the southern parts of both WSAs the coal is covered by Tertiary and Quaternary sediments and volcanic rocks. No specific mines or prospects have been identified, but the

coal is a known resource. Similar coals of the Crevasse Canyon Formation have been explored in the Datil Mountain coal field about 30 miles to the east (Frost, Tabot, and Campbell, 1979). In the Salt Lake Coal Field, two zones of B to C grade bituminous coal have been identified. The lower Cerro Prieto zone contains coal ranging from 4 to 13 feet in thickness, while the upper Rabbit Zone is thinner. Portions of the GRA north and northeast of the Eagle Peak WSA have been leased for coal by the State of New Mexico (Bill Jonas, 1983, written comm.). The New Mexico Bureau of Mines and Mineral Resources and the U.S. Geological Survey have estimated the coal resources of the Salt Lake coal area (which is slightly larger than the Salt Lake GRA) at 320 million tons (Kottlowski, et al., 1982).

Uranium

There are two known uranium prospects in Mesaverde rocks in T3N-R16W, sections 21 and 22. These are one mile east of the GRA boundary and eight miles northeast of the Eagle Peak WSA at its closest point. These prospects were listed by Hilpert (1969, p. 33) as follows:

Name:	Varnum
Location:	NE1/4 Sec. 21, T3N-R16W
Description:	Mineralized sandstone in the Mesaverde Group
Name:	Mangum
Location:	Sec. 22, T3N-R16W
Description:	Coaly shale bed about 3 inches thick, 75 feet below the top of the Mesaverde Group. Sample 0.03% eU.

At about the same location, a minor uranium deposit (the Hogback No. 4 deposit) in gray sandy shale of the Mesaverde Group was listed by Finch (1967). The same deposit was also noted in the NURE report on the St. Johns quadrangle (Texas Instruments, 1969).

In the NURE airborne radiometric survey of the St. Johns quadrangle, three possible uranium prospects were identified within the Salt Lake GRA.

These are all in the northeast part of the GRA. One is in the area of Mesaverde outcrop near the north boundary of the GRA and two are in the east part of the Eagle Peak WSA near the south edge of the Mesaverde outcrop area.

These are shown on figure 2 and are listed below:

1. Unnamed
Location*: SW1/4 Sec. 1, T3N-R18W
Description: Airborne radiometric anomaly
Reference: Texas Instruments, 1979
2. Unnamed
Location*: SW1/4 Sec. 24, T2N-R18W
Description: Airborne radiometric anomaly
Reference: Texas Instruments, 1979
3. Unnamed
Location*: SE1/4 Sec. 22, T2N-R17W
Description: Airborne radiometric anomaly
Reference: Texas Instruments, 1979

*Locations are approximate because exact locations were not given in the original reference.

Oil and Gas

The northwest part of Catron County has a low favorability for oil and gas. Consequently the area has been little explored. There have been three exploratory tests for oil and gas within the Salt Lake GRA, as of July 1982, according to the petroleum exploration maps maintained by the New Mexico Bureau of Mines and Mineral Resources. These are shown on figure 5 of this report and are listed as follows:

Cleary #1

Farm name: Wheeler
Location: SW1/4, NE1/4, Sec. 6, T3N-R16W
Total Depth: 2605 feet

Skelly #1

Farm name: Teel
Location: SE1/4, SW1/4, Sec. 7, T2N-R19W
Total Depth: 2365 feet

TransOcean #1

Farm name: State
Location: SW1/4, Sec. 12, T2N-R18W
Total Depth: 4275 feet

No shows of oil or gas were recorded in any of the above tests. However, in both WSAs (Mesita Blanca and Eagle Peak) there is a sedimentary rock thickness of about 4000 feet. These are known reservoir rocks and possible source rocks; there is a potential for petroleum, although it is low.

Mining Claims, Leases, and Material Sites

An area of four square miles around the Zuni Salt Lake (see figure 2) has been classified as prospectively valuable for sodium (DeCicco and Patterson, 1979), including a small area at the north end of the Eagle Peak WSA. In the same classification, most of the GRA including all of both WSAs have been classified as prospectively valuable for oil and gas.

According to the information on mining claims furnished from the BLM, New Mexico State Office, there are no existing mining claims within the Mesita Blanca WSA or the Eagle Peak WSA. It seems likely that there may be some claims in the two WSAs, and that the information has not yet appeared in the BLM state office files. According to information furnished by the BLM, there has been exploration drilling in the Mesita Blanca area, directed at uranium targets in the Baca Formation.

The areas of past production of sand and gravel and construction stone have been listed and discussed earlier in this report.

To the writers' knowledge there are no oil and gas leases or coal leases within the Mesita Blanca WSA or the Eagle Peak WSA.

Mineral Deposit Types

The only known deposits of GEM Resources within the Salt Lake GRA are salt, sand and gravel, construction stone (basalt), and bituminous coal. Of these, all except the coal have produced. The coal is undeveloped but is a

known resource and possibly it is the most important known GEM Resource in this GRA. There is a possibility of petroleum but northwest Catron County is regarded as having a low potential for petroleum. In a statewide assessment of petroleum potential by the New Mexico Bureau of Mines and Mineral Resources (Foster and Grant, 1974), this area was rated in the least favorable category for oil and gas.

There is a possibility of uranium deposits in the Tertiary volcanic rocks and the associated sediments, and also in the Baca Formation, Chinle Formation, and possibly in other Mesozoic formations. There is a possibility of tin deposits in the Datil Formation although there are no known tin prospects in the Salt Lake GRA.

In this resource assessment, as in any evaluation of this kind, the most important resource may be the one that no one has thought of yet. For example, prior to about 1900 there was little known about molybdenum deposits and little reason to think they would be valuable. Prior to about the same time, essentially nothing was known about the occurrence of uranium in sedimentary rocks. Until comparatively recently there was no thought of looking for beryllium deposits in volcanic or volcanoclastic rocks.

This report attempts to consider all the GEM Resources for which there is any specific evidence within the Salt Lake GRA or in its vicinity. However, the Salt Lake GRA could contain important deposits of zeolites, valuable clay minerals, gold, silver, various kinds of gemstones, or beryllium, to name but a few.

Mineral Economics

In the Salt Lake GRA there are resources of commodities of low unit value such as sand and gravel and construction stone. The past production of these commodities has been strongly influenced by proximity and access to

U.S. Highway 60 and the secondary roads joining to it. Some of these resources have been developed and others could be developed if needed. The other two known resource commodities in the Salt Lake GRA are salt and coal. Salt has been produced by evaporation of the brines from the Zuni Salt Lake. The coal resources have not been developed, because the area is remote from markets and because coals of comparable quality are available from more accessible locations.

Basically two factors have deterred exploration and development in northwest Catron County. These are the geographic remoteness of the area and the Tertiary/Quaternary cover of volcanics and of alluvial sediments. There have not been enough near-surface indications of ore to encourage much deep drilling, although some uranium prospects have been identified as noted previously in this report.

Commodities of high unit value such as uranium or petroleum could be readily marketed if discovered, since transportation distance would not be a significant factor in these cases.

Strategic and Critical Minerals and Metals

There are no known deposits or prospects of strategic and critical commodities within the Salt Lake GRA. There is possibly a favorable environment for tin in the Tertiary volcanics of the Datil Formation which are present mainly in the Eagle Peak WSA and farther southeast. The felsic (rhyolitic) units of the Datil Formation are known to contain significant tin deposits in southeastern Catron County and northwestern Sierra County, about forty miles southeast of the Salt Lake GRA. The favorable rhyolitic units of the Datil Formation have not been mapped in the Salt Lake GRA but have been recognized about 15 miles east of the GRA. They may also be present within the Salt Lake GRA.

**LAND CLASSIFICATION FOR GEOLOGY, ENERGY
AND MINERAL RESOURCES POTENTIAL**

The classification scheme used in this report uses a two fold system of designation to describe (after BLM, Technical Specification, Attachment 9, dated March 24, 1982):

1. the favorability for the occurrence of GEM Resources, and
2. the level of confidence of the estimate.

The designations used are 1 through 4 and A through D, respectively:

Classification Scheme

1. The geologic environment and the inferred geologic processes do not indicate favorability for accumulation of mineral resources.
2. The geologic environment and the inferred geologic processes indicate low favorability for accumulation of mineral resources.
3. The geologic environment, the inferred geologic processes, and the reported mineral occurrences indicate moderate favorability for accumulation of mineral resources.
4. The geologic environment, the inferred geologic processes, the reported mineral occurrences, and the known mines or deposits indicate high favorability for accumulation of mineral resources.

Level of Confidence Scheme

- A. The available data are either insufficient and/or cannot be considered as direct evidence to support or refute the possible existence of mineral resources within the respective area.

- B. The available data provide indirect evidence to support or refute the possible existence of mineral resources.
- C. The available data provide direct evidence, but are quantitatively minimal to support to refute the possible existence of mineral resources.
- D. The available data provide abundant direct and indirect evidence to support or refute the possible existence of mineral resources.

Mesita Blanca and Eagle Peak WSAs-Salt:

Salt is produced by evaporation of brine at the Zuni Salt Lake in the southwest part of T3N-R18W; the resource classification for salt in that area is 4-D. There are other undrained depressions in the same vicinity that have potential for similar production of salt but these are all outside the two WSAs. These areas are designated 3-C on the accompanying map. The entire GRA and both WSAs are classified 1-C except as indicated on the map (fig. 4).

Mesita Blanca WSA-Coal:

The coal resources of the Salt Lake GRA are associated with the middle and upper parts of the Crevasse Canyon Formation of the Mesaverde Group. The outcrop area of the Gallup Sandstone (lowest unit of the Mesaverde Group in this area) is excluded. The Gallup interval contains important coal resources elsewhere in northwest New Mexico but is not known to be coal-bearing in the area of the Salt Lake GRA.

Sub-area 1 (4-C). This is the outcrop area of the coal-bearing units of the Crevasse Canyon Formation (fig. 5).

Sub-area 2 (2-C). In these areas the Crevasse Canyon Formation is absent. There is a low potential for coal (fig. 5) because of the

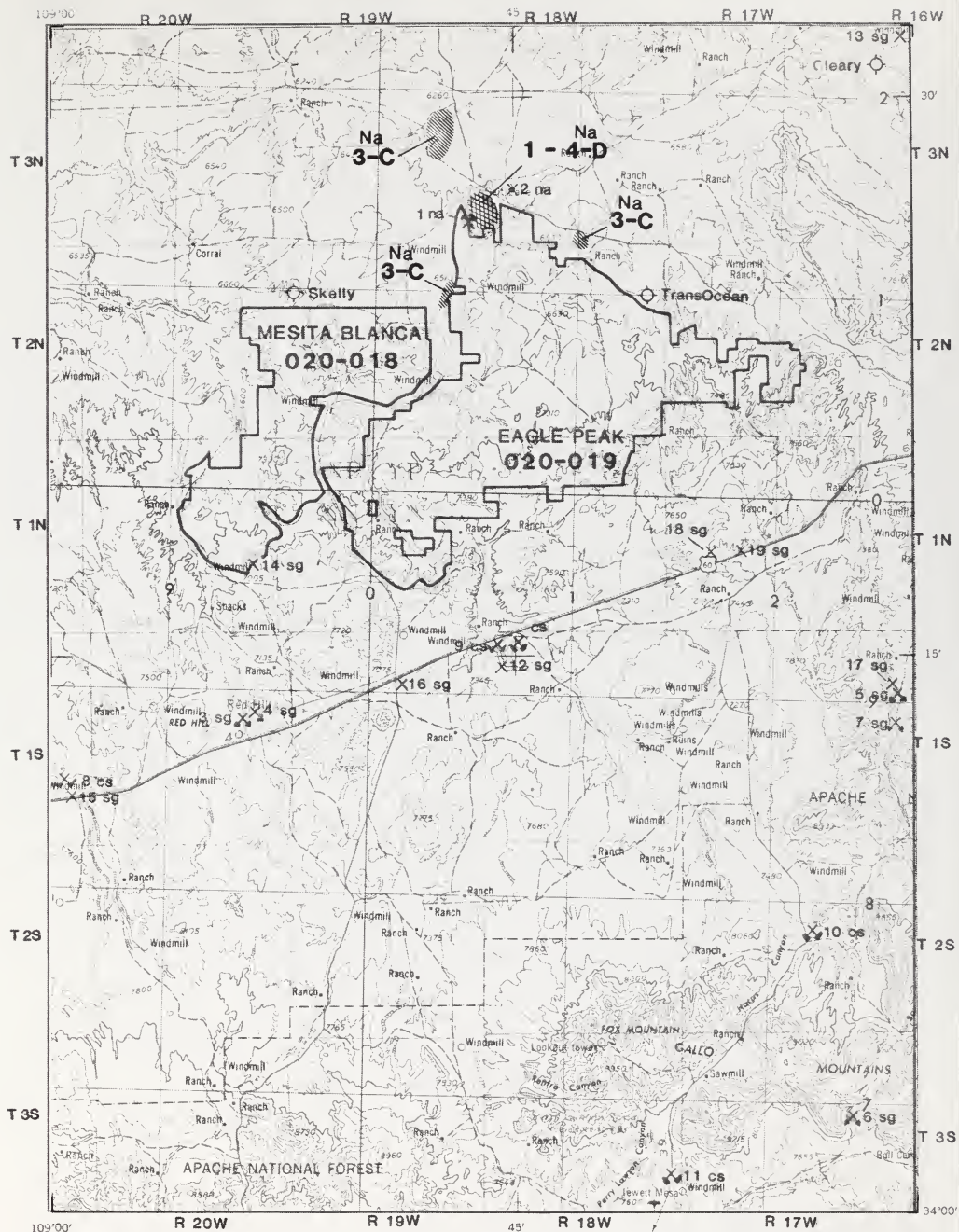


FIG.4 FAVORABILITY POTENTIAL AND LEVEL OF CONFIDENCE MAP FOR SALT RESOURCES OF THE SALT LAKE AREA, NEW MEXICO.

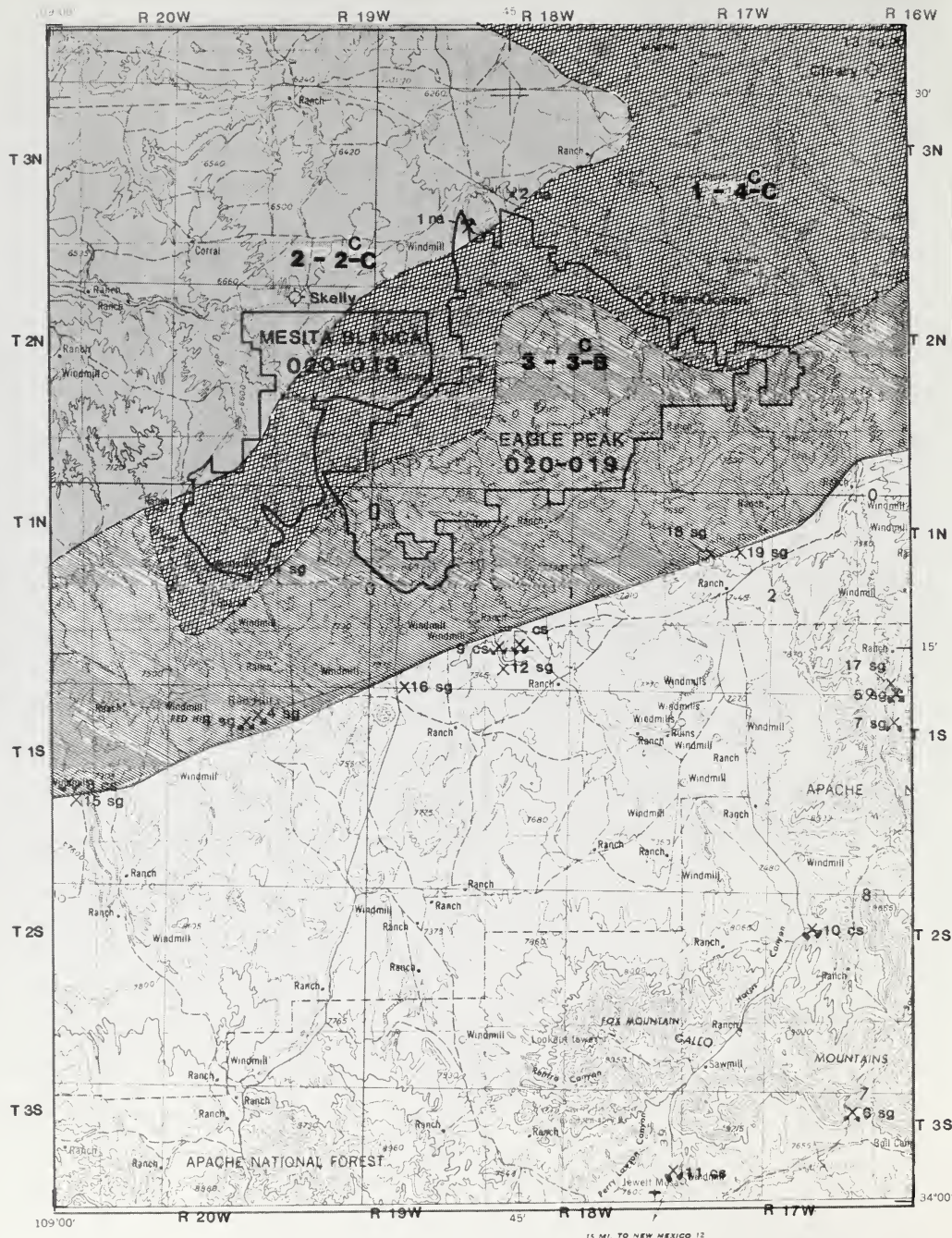


FIG.5 FAVORABILITY POTENTIAL AND LEVEL OF CONFIDENCE MAP FOR COAL RESOURCES OF THE SALT LAKE AREA, NEW MEXICO.

possibility of coal in the Gallup Sandstone (as noted above). There is also a possibility of coal in the subsurface in the Dakota Sandstone.

Eagle Peak WSA-Coal:

5). **Sub-area 1 (4-C).** Same comment as in the Mesita Blanca WSA (fig.

5). **Sub-area 2 (2-C).** Same comment as in the Mesita Blanca WSA (fig.

Sub-area 3 (3-B). This is the southeast part of the WSA, where the coal-bearing units of the Crevasse Canyon Formation are covered by younger rocks. The coal-bearing units are present but the favorability is lower because of the potentially higher cost of mining (fig. 5).

Mesita Blanca and Eagle Peak WSAs (2-C)-Oil and Gas:

The entire area of the Salt Lake GRA is classified as having a low favorability for oil and gas (fig. 6). There is no evidence to justify different classifications in any parts of the two WSAs. The area around the dry holes in the north part of the GRA have a lower favorability, but these are outside the WSAs.

Also, the entire WSA has a low favorability for oil and gas, but the available information is sparse. There have been dry holes drilled near the WSA but not within the WSA. There are known reservoir rocks and possible source rocks so, the area cannot be entirely discounted for oil and gas potential deposits

Mesita Blanca WSA-Sand, Gravel, and Construction Stone:

The most favorable areas for the development of these resources are the areas with good access to U.S. Highway 60 and to secondary roads leading to it. The known past producers and most of the known deposits and prospects

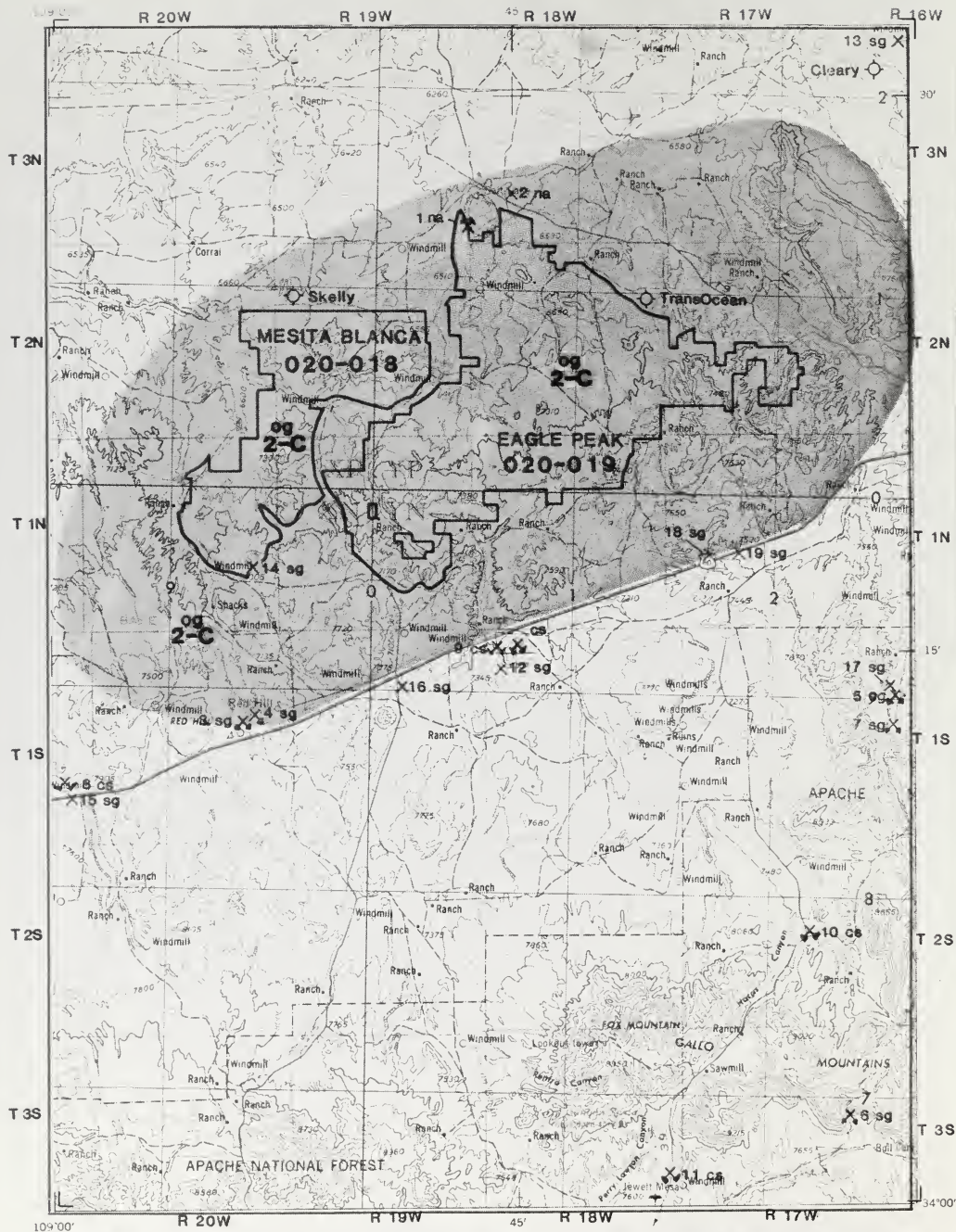


FIG.6 FAVORABILITY POTENTIAL AND LEVEL OF CONFIDENCE MAP FOR OIL AND GAS RESOURCES OF THE SALT LAKE AREA, NEW MEXICO.

are along these roads and are south of the WSAs. Only one known prospect is near the WSAs. This prospect is located in Sec. 24, T1N-R20W, which is at the south end of the Mesita Blanca WSA. Within the WSAs the outcrop area of the Cretaceous rocks has a low favorability and the other areas are moderately favorable for these commodities (fig. 7).

Sub-area 1 (3-C). This is mainly the outcrop area of Quaternary basalt and associated volcanic and sedimentary rocks of Tertiary and Quaternary age. The classification boundary does not coincide exactly with the geologic contacts because there are small unmapped areas of surficial deposits such as talus and alluvium around the mapped volcanic areas.

Sub-area 2 (2-C): This is the outcrop area of Cretaceous sedimentary rocks, mainly Mesaverde Group and Mancos Shale. These rocks have a low favorability for sand, gravel, and stone; and also the areas do not have good access to U.S. Highway 60.

Eagle Peak WSA-Sand, Gravel and Construction Stone

Sub-area 1 (3-C). Comments are the same as for the Mesita Blanca WSA.

Sub-area 2 (2-C): Comments are the same as for the Mesita Blanca WSA. The area around the Zuni Salt Lake is not classified because it is outside the WSA.

Mesita Blanca and Eagle Peak WSAs-Tin and Uranium

These two commodities are known to be associated with felsic volcanic rocks such as those found in some units of the Datil Formation. There are no classification maps for these two commodities in this report because the favorable felsic volcanic units have not been identified in the Salt Lake GRA. However, more detailed mapping of the Datil Formation might very well

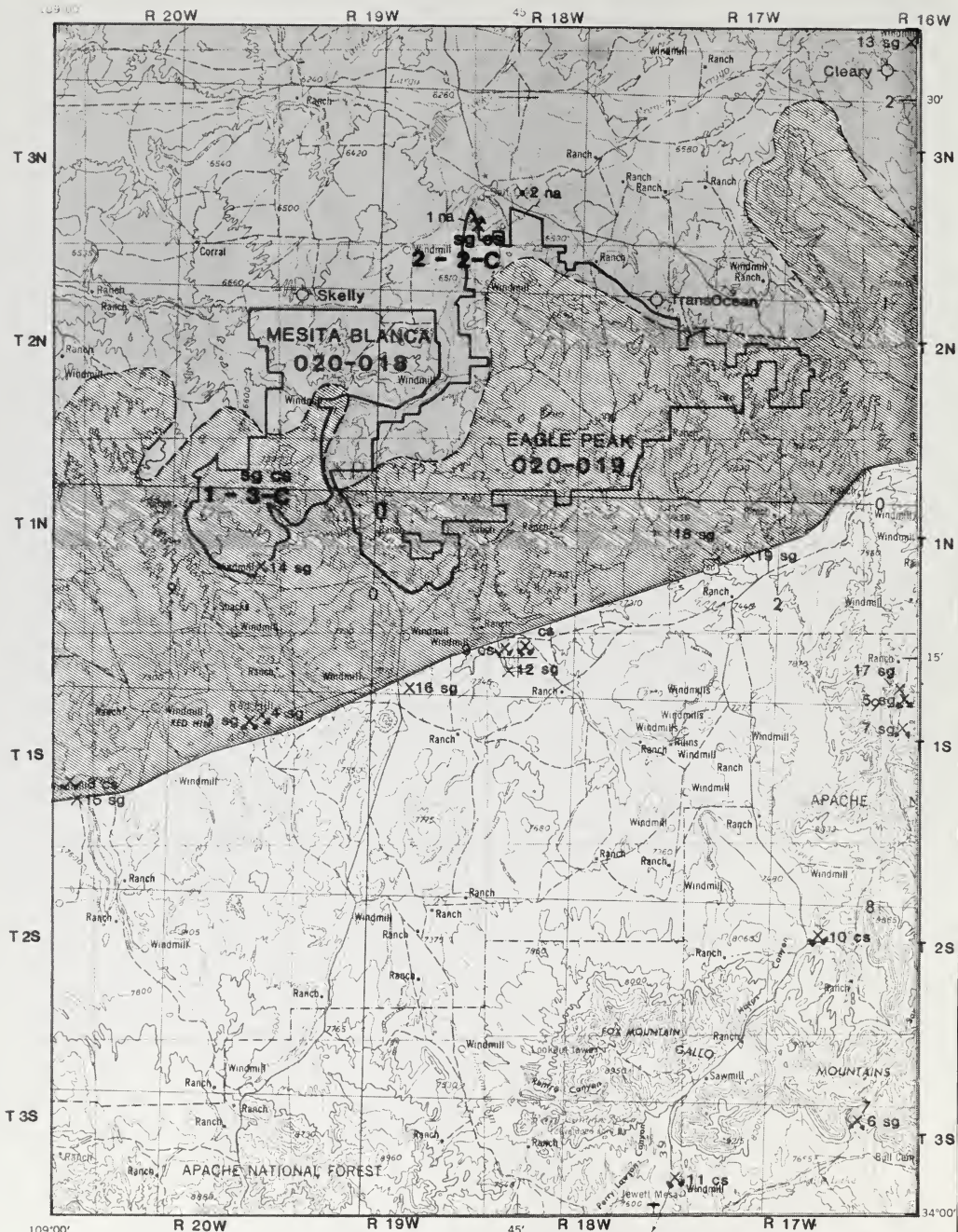


FIG.7 FAVORABILITY POTENTIAL AND LEVEL OF CONFIDENCE MAP FOR SAND, GRAVEL AND CONSTRUCTION STONE RESOURCES OF THE SALT LAKE AREA, NEW MEXICO.

find such favorable units. Because tin is a strategic and critical metal, the possibility is of greater importance.

There are no known tin prospects in the Salt Lake GRA, and only a few minor prospects of uranium. These are shown on figure 2. In the case of uranium there is also a potential in the Mesozoic and Tertiary sedimentary rocks.

RECOMMENDATIONS

In order to improve the assessment of GEM resources, a field examination is highly recommended, particularly in the outcrop areas of the Datil Formation (volcanic rocks). The objective would be to assess the possibility of felsic volcanic units that might be favorable host rocks for tin and uranium. A scintillation counter should be carried during this work and rock and stream (or dry wash) sediment samples should be collected and analyzed.

A more detailed evaluation of the oil and gas potential should be made, including the purchase of all available data from commercial services.

The area around the Zuni Salt Lake should be examined to look for any further resources of salt that may occur in the northern part of the Eagle Peak WSA.

REFERENCES

- Anderson, O.J., 1981a, Abandoned or inactive uranium mines in New Mexico: New Mexico Bureau of Mines and Mineral Resources Open-File Report 148.
- _____, 1981b, Geology and coal resources of Cantarelo Springs 7 1/2 minute quadrangle: New Mexico Bureau Mines and Mineral Resources Open-File Report 142.
- Berg, A.W., and Carrillo, F.V., 1980, MILS: The mineral industry location system of the Federal Bureau of Mines: U.S. Bureau of Mines, information circular 8815, 24p.
- Brobst, D.A., and Pratt, W.P., editors, 1973, United States mineral resources: U.S. Geological Survey Professional Paper 820.
- Campbell, F., 1981, Geology and coal resources of Cerro Prieto and Dyer quadrangle: New Mexico Bureau Mines and Mineral Resources Open-File Report 144.
- Cummings, D., 1968, Geologic map of the Zuni Salt Lake volcanic crater, Catron County, New Mexico: U.S. Geological Survey Miscellaneous Investigations Map I-544.
- Dane, C.H. and Bachman, G.O., 1965, Geologic map of New Mexico: U.S. Geological Survey, 2 sheets.
- DeCicco, D.A., and Patterson, E.D., 1979, Leasable mineral and waterpower classification map of the Saint Johns quadrangle, Arizona, New Mexico: U.S. Geological Survey open-file report 79-731.
- Finch, W.I., 1967, Geology of epigenetic uranium deposits in sandstone in the United States: U.S. Geological Survey Professional Paper 538.
- Foster, R.W., and Grant, P.R., Jr., 1974, The future of New Mexico's oil and gas resources: New Mexico Bureau Mines and Mineral Resources RM-3.
- Frost, S.J., Tabet, D.E., and Campbell, F.W., Coal exploration drilling in the Datil Mountain coal field: New Mexico Bureau Mines and Mineral Resources Open-File Report 111.
- Hilpert, L.S., 1969, Uranium resources of northwestern New Mexico: U.S. Geological Survey Professional Paper 603, 166 p.
- Kottlowski, F.E., Campbell, F.W., Roybal, G.H., and Martinez, L.B., 1982, New Mexico (coal resources): 1982 Keystone Coal Industry Manual, p. 586-595.
- Maassen, L.W., 1980, Uranium hydrogeochemical and stream sediment reconnaissance, Saint Johns NTMS quadrangle, Arizona/New Mexico, including forty-two additional elements: U.S. Department of Energy, GJBX-191(80).
- May, R.T., Foster, M.G., Daw, P.E., Brouillard, L.A., and White, D.L., 1980,

- Uranium resource evaluation of the Saint Johns quadrangle, Arizona and New Mexico, prepared for the U.S. Department of Energy, Grand Junction, Colorado, PGJ-011(80).
- Milligan, M.H., and Birdseye, H.S., 1968, Preliminary geological report, Datil area uranium prospect, Socorro and Catron Counties, New Mexico: Unpublished report, available in files of U.S. Bureau of Land Management, Socorro, New Mexico, 13 p.
- Northrup, S.A., 1961, New Mexico's fossil record: New Mexico Quarterly, v. 32, no. 1 and 2, 74 p.
- Quahada Engineering, 1979, Geology of the St. Johns quadrangle: U.S. Department of Energy, Specification 1125B, Bendix Field Engineering Corporation, Grand Junction, Co.
- Robertson, R.S., 1956, Chinle (Triassic) stratigraphy of St. Johns vicinity, Apache County, Arizona (M.A. thesis): Austin, University of Texas, 59 p.
- Snyder, D.O., 1971, Stratigraphic analyses of the Baca Formation in west-central New Mexico (M.A. thesis): Albuquerque, University of New Mexico, 158 p.
- Smith, H.L., 1956, Cretaceous stratigraphy of the Carrizo drainage basin, Apache County, Arizona and Catron and Valencia Counties, New Mexico (M.A. thesis): Austin, University of Texas, 90 p.
- Tabet, D.E., and Frost, S.J., 1978, Coal fields and mines of New Mexico: New Mexico Bureau Mines and Mineral Resources, Resource Map no. 10 with text.
- Texas Instruments Inc., 1979, Aerial radiometric and magnetic reconnaissance survey of portions of Arizona, Idaho, Montana, New Mexico, South Dakota, and Washington, Final Report, v. 2-L, St. Johns quadrangle: GJBX-126(79).
- U.S. Bureau of Mines and U.S. Geological Survey, 1976, Coal resource classification system of the U.S. Bureau of Mines and U.S. Geological Survey: U.S. Geological Survey Bulletin 1450-B, 7 p.
- _____, 1980, Principles of a resource/reserve classification for minerals: U.S. Geological Survey Circular 831, 5 p.
- U.S. Geological Survey, 1965, Mineral and water resources of New Mexico: New Mexico Bureau Mines and Mineral Resources Bulletin 87, 437 p.
- Willard, M.E., 1957, Reconnaissance geologic map of Pinonville thirty-minute quadrangle, Catron County: New Mexico Bureau Mines and Mineral Resources Geologic Map no. 3.
- Willard, M.E., and Weber, R.H., 1958, Reconnaissance geologic map of Canon Largo thirty minute quadrangle, Catron County: New Mexico Bureau Mines and Mineral Resources Geologic Map no. 6.

Willard, M.E., Weber, R.H., Foster, R.W., and Kottlowski, F.E., 1959, Road log; Gallup to Socorro via Zuni, Pueblo, Fence Lake, Salt Lake, and Quemado: Guidebook, Tenth Field Conference of New Mexico Geological Society; Albuquerque, p. 37-46.

